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A BRIEF REVIEW OF RECENT PROGRESS IN
SOLAR PHYSICS.

BY HEBER D. CURTIS.

ANNALES L'OBSERVATOIRE D'ASTRONOMIE PHYSIQUE DE PARIS,
SIS PARC À MEUDON. Tome I, 1896.

— ATLAS DES PHOTOGRAPHIES SOLAIRES. Tome I, 1903.

THE RUMFORD SPECTROHELIOGRAPH OF THE YERKES OBSERVATORY. *Publications of the Yerkes Observatory*, Vol. III, Part I, 1903.

ANNALS OF THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION. Vol. I, 1900.

INTENSITÉ DE LA RADIATION SOLAIRE A DIFFÉRENTES ALTITUDES. RECHERCHES FAITES A TÉNÉRIFFE 1895 ET 1896 PAR KNUT ÅNGSTRÖM. *Nova Acta Reg. Sec. Scient. Upsaliensis* XX, fasc. I, 1901.

REPORT OF THE COMMITTEE ON SOUTHERN AND SOLAR OBSERVATORIES. Published by the Carnegie Institution, 1903.

Although the researches covered by these superbly printed volumes in some cases reach back twenty years or more, the recent publication of the results secured may warrant a brief résumé of the progress recorded in these epoch-marking monographs.

It is a far cry from the first daguerreotype of the Sun, made in 1845 by FIZEAU and FOUCAULT, to the great plates of the Meudon folio, photographed for the most part on a scale of 0^m.30 to the Sun's diameter and enlarged to a solar diameter of 1^m.20. In the volume of the Annals the plates have been

enlarged to a solar diameter of $0^m.894$; and as the plates given in the Atlas cover the same general ground and the letter-press is practically a reprint of that in the Annals, it is possible that many will consider the partial duplication of work in the Atlas an expenditure not warranted by the additional results made accessible. There can be no question, however, as to the beauty of this fine folio, or the excellence of its great prints, nearly eighteen by twenty-one inches in size. The photographs were secured with a telescope and lens by PRAZMOWSKI, $0^m.135$ (5.3 in.) in aperture, described by M. JANSSEN as of rare optical perfection. In the taking of the plates of this series as large as possible a measure of monochromatism was sought for. This result has been achieved by careful choice and figuring of the glass of the lens to secure a sharply defined maximum of photographic effect near G. In like manner the collodion plates employed were composed from formulæ found by experiment to give a similar maximum, quite limited in extent, at the same region of the spectrum, and great pains were taken and special precautions employed in the manufacture of the collodion emulsion to secure plates of exceeding fineness of grain. The negatives were generally on a scale of $0^m.30$, though sometimes $0^m.50$, or even $0^m.70$, was employed. Some of the plates show a sharpness and fineness of detail which it would be difficult to improve. Plates I, III, XIX, and XXI are unusually good. The average size of the granulations is from one to two seconds of arc, though not infrequently details can be seen measuring not more than one fourth to one third of a second.

One of the more important of M. JANSSEN's results, aside from the granular structure itself and the relegation of "willow-leaf" to the limbo of discarded theory, is the fact that the granular structure generally persists right up to the visually much brighter edge of spots and through the striæ of spot penumbraë. Moreover, there seems to be no essential difference in the granulations at the poles as compared with the central regions. Many of the plates show quite plainly the so-called *réseau photosphérique*, or network, in which these granulations are frequently arranged, generally of a roughly polygonal form. The nature of the granulations seems to be entirely analogous to roughly spherical clouds floating in a

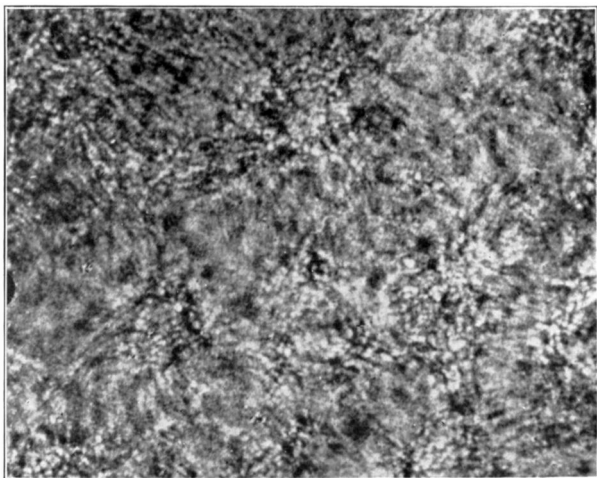


FIGURE 1.—A portion of Plate IX, *Meudon Atlas des Photographies Solaires*.

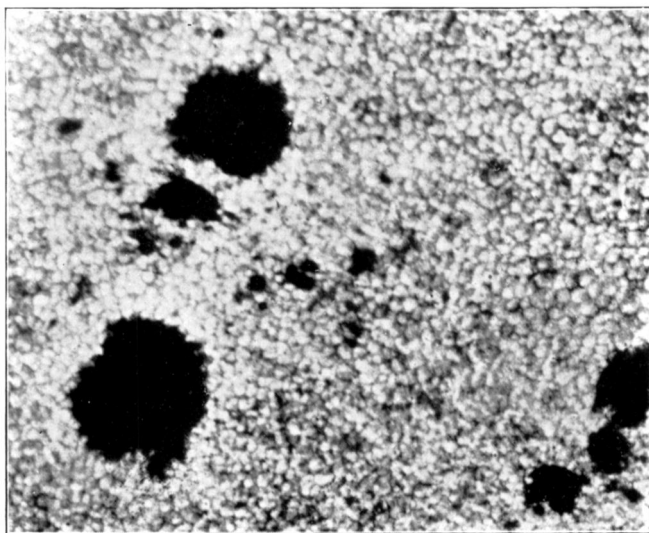


FIGURE 2.—A portion of Plate XIX, *Meudon Atlas des Photographies Solaires*.

less luminous medium. JANSSEN estimates that were the entire solar surface of the same radiating power as the granulations the intensity of the solar radiation would be quintupled. The *réseau* JANSSEN holds to be a result of different stages in the development of the granulations. The solar surface is composed of sections relatively quiescent while adjacent regions are in a condition of great activity. This can be seen easily in Figure 1, which is a small section of Plate IX of the Atlas, on nearly the same scale. Where the regions of quiescence obtain the granulations are sharp and well-defined. In adjacent regions of greater activity the separate grains merge into a more or less confused whole, the sum total giving the effect of a network or pattern. Sometimes the figures of the "pattern" are much smaller than at others, and at times they may be a minute of arc or more in diameter. In Figure 2, taken from Plate XXI, the network is wanting, and the granulations are very well defined and show an approximately spherical form.

M. JANSSEN's theory of the *réseau photosphérique* has been given here, although it has more than once been called in question. It has been pointed out that this phenomenon may instead be produced in our own atmosphere, or even within the telescope itself. It has often been asked why two photographs could not be taken very close together to settle this objection once for all (*cf.*, among others, LANGLEY, *Amer. Jour.*, XV., pp. 297 ff.). This may be more difficult than it seems, as the conditions of good seeing necessary for a perfect plate are generally very brief. But it would seem to be possible to take two such plates, and that even if one was of inferior quality, definite evidence as to the true solar character of the *réseau* might be secured. No more recent statement of this hypothesis is given in these volumes than M. JANSSEN's original announcement of discovery made in 1877 and reprinted in both the Annals and the Atlas. In view of Dr. HALE's experiences with brief intervals of poor seeing in his spectroheliographic work and Professor LANGLEY's experiments on improved images secured by mechanical stirring of the air in the telescope-tube or immediately in front of the lens, the solar character of the *réseau* would seem to be open to doubt till absolutely confirmed by consecutive exposures at brief intervals.

The Meudon photographs are to a considerable extent monochromatic, as they are taken with light from a small and sharply limited portion of the spectrum. They represent perhaps the highest present development in the study of the solar surface from methods purely photographic in their nature. In the researches of Dr. HALE and his assistant, Mr. ELLERMAN, we have this principle of monochromatism pushed to its logical conclusion, and with the aid of the spectroheliograph it is now possible to take photographs of the solar surface in light which is purely monochromatic. The principle of the instrument, though well known, will bear restatement in this résumé; it is most simple in theory for all its ingenuity, but must require a very high degree of what may perhaps best be termed instrumental ability for the securing of the excellent photographs shown in the fine plates of this volume. A long, curved slit admits light to a powerful spectroscope, preferably a combination of grating and prisms to secure a sufficiently high dispersion and freedom from diffused light. From the resulting spectrum a given line is segregated by means of a second slit, behind which is placed the photographic plate. This arrangement would then give a photograph of a narrow line on the solar surface in light of the chosen wave-length. To secure the photograph of an area or of the entire solar disk the Sun's image must be made to travel across the first slit, while the photographic plate is made to travel past the second slit in synchronism with the movement of the solar image. This gives the entire area in light which is purely monochromatic and furnishes a powerful method of research, of which it is not at all too much to say that no more marked advance in the study of the Sun's surface has ever been made. Moreover, as successive photographs can be taken in light of the same substance at different wave-lengths, or even at different portions of a broad band, astrophysics has gained a method of which it may well be predicted that not a little light will eventually be thrown on more general physical and chemical problems, gained from the behavior of matter in a monster laboratory whose conditions we can never hope to duplicate by methods purely terrestrial.

The volume gives a description of the new Rumford spectroheliograph, much more powerful than Dr. HALE's previous

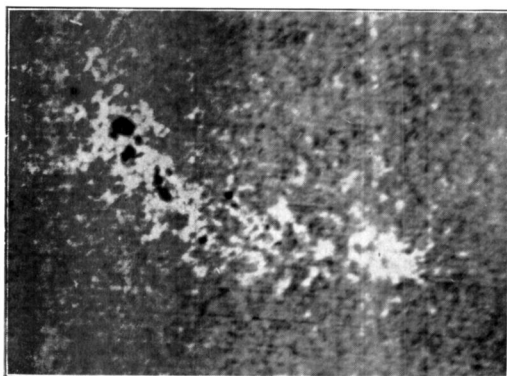


FIGURE 3.—Calcium Flocculi, photographed with light from the lower K_1 level.

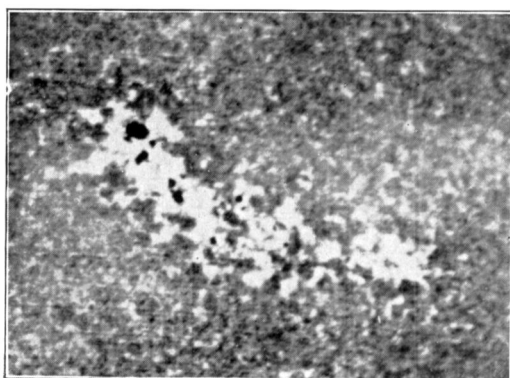


FIGURE 4.—The same Flocculi photographed with light from the K_2 level.

(Figures 3 and 4 are from *Publ. Yerkes Obs.*, Vol. III, Part I., Plate V.)

instruments, and a statement of the results thus far secured. By this method Dr. HALE has taken numerous photographs by the light from different portions of the H and K bands, the calcium line at $\lambda 4226$ and $H\beta$. Attempts have also been made to use some of the stronger iron lines, but for this latter purpose it is found that a more powerful equipment will be needed.

In general the calcium "focculi" photographed with light from H and K are of dimensions about the same as those of the granulations on the Meudon photographs, and are probably different views of the same formation. But the greatest interest attaches to the photographs made in light of different wave-lengths of the same substance. Marked differences are found, according as the calcium focculi are photographed in light of the H and K bands at their broadest, called by the authors H_1 and K_1 , or in their narrowed state as they appear in the lower levels of the chromosphere (H_2 , K_2). Eventually it is hoped to be able to secure impressions with these lines in their still narrower state as they appear in the upper chromosphere and prominences (H_3 , K_3). It will be noted in Figures 3 and 4 that the photograph from light at the K_2 level shows the focculi spread over a much greater area than the plates taken at the lower levels of K_1 . Undoubtedly these differences are due to the fact that these photographs represent different *levels* of the calcium vapor in the focculi. We get, then, in effect, several *cross-sections* of a focculus, and in general the evidence points to a "structure composed of expanding columns of calcium vapor." Considerable differences have likewise been found between photographs made with H and K light, as compared with those taken from the calcium line at $\lambda 4226.9$ — differences which the authors prefer to leave for tests with more powerful apparatus to explain. *Dark* calcium focculi have also been photographed. The photographs taken with light from the hydrogen line at $H\beta$ show that the focculi due to this element are in general dark, though bright in exceptional cases. The hope is expressed that with a larger solar image and higher dispersion it may later be possible to photograph the hydrogen focculi at different levels as has already been done for calcium.

It would be futile to try to estimate the importance of this

advance in methods for the study of all solar eruptive phenomena. It is not improbable that much evidence will eventually be secured on theories of dissociation and chemical combination in fields but remotely connected with astronomical science. The essentials for future progress in photoheliographic work are a larger solar image, greater dispersion in the instrument, and, most important, good day conditions of "seeing," requirements which are now being secured.

No outline of recent progress in solar physics would be complete without reference to the bolometric work of the Astrophysical Observatory of the Smithsonian Institution. As in the case of some of the other volumes noted in this summary, inasmuch as the work covered dates back over twenty years to its inception by Professor LANGLEY, it might be more fitting to regard it as a recently erected landmark of past progress. Under Professor LANGLEY at Allegheny and the Smithsonian Institution, and later in the skilled hands of ABBOT, the original bolometer has been improved with the use of prisms of rock-salt, constant-temperature control, almost automatic photographic registration of results, and galvanometers of the most extreme sensitiveness, till the infra-red spectrum has been mapped from λ 7600, the limit of the visual spectrum, to λ 53000, a stretch of previously unknown spectrographic territory eight times as large as all that had been known before. Aside from its purely theoretical interest, the study of this long stretch of invisible solar thermal radiation, the determination of the circumstances of its absorption by our atmosphere, and its possible variations during a sun-spot period are questions of the highest economic importance.

In this connection the observations of the solar constant made simultaneously at different altitudes on the island of Ténériffe by ÅNGSTRÖM are of interest. His work is noted here not because of any novelty in the results, for other similar investigations have been carried out, but because in the employment of the compensation pyrheliometer devised by him we have what will probably prove to be a very distinct advance over former instrumental means for determining the solar constant. Though described in the Upsala publications and also in the *Astrophysical Journal* (Vol. IX, pp. 399 ff.), a brief outline of its principle may not be out of place. Two

precisely similar blackened strips of platinum are connected with the terminals of a thermopile. One of these strips is exposed to the rays of the Sun, the other is covered by a screen. The rise in temperature in the exposed strip is compensated in the screened strip, and at the same time measured, by electrically heating it the same amount, the thermopile, in connection with the employment of delicate electrical measuring devices, forming a very sensitive thermal balance. As the strip which receives the radiation is under precisely the same conditions as the strip which measures the amount of the radiation, many troublesome corrections are obviated and the speed of the determinations is very much higher than in other forms, a few seconds instead of three to five minutes or longer.

Plans for the future are frequently the best norm of past progress. The Report of the Committee of the Carnegie Institution on Southern and Solar Observations is a most clear, definite, and straightforward presentation of the most pressing present-day problems in astronomy and astrophysics. The report makes very interesting reading, and it gives indirectly, through its plans for future work, a clear conspectus of the present boundaries in these sciences. Astronomers cannot fail to feel that the committee has wisely and without bias chosen the most fruitful lines for future research in astronomy and astrophysics; this the more, as the report is in many ways a summation of the opinions of the leaders, both American and foreign, in these sciences. An appendix is devoted to these opinions in the form of letters written to the committee, and they show on the whole great unanimity.

The recommendations for the solar observatory contemplate a main station and two substations. At the main station, aside from researches on stars and nebulae, the solar work will be limited to two or three definite lines of research.

(1) "Frequent measurement of the solar constant, together with studies on the absorption of the solar atmosphere and the radiation of different portions of the Sun's image, such as spots, faculae, and prominences. The principal instruments needed for this research are a 16-inch cœlostat and a large spectrobolometer for the solar constant work, and a 30-inch cœlostat with concave mirror of about 200 feet focal length,

for providing a solar image suitable for detailed radiation work."

(2) "Systematic observations, with large spectrographs and spectroheliographs, on such problems as the solar rotation, the structure and nature of sun-spots, faculæ, etc., and other problems related to the solar constitution. For this work there will be required two 30-inch cœlostats, used in conjunction with objectives and mirrors ranging in focal length from 64 feet to 200 feet; two large plane-grating spectroscopes, having focal lengths of about 21 feet and 42 feet respectively, provided with auxiliary for work with the spark and arc; a three prism spectroheliograph of about 10 inches aperture, and a three-prism spectroheliograph of 8 inches aperture and about 33 feet focal length."

Great care has been taken that no mistake should be made in the selection of the site for this important station, and in an appendix is given the full and interesting report of Professor W. J. HUSSEY's thorough search for the best conditions of seeing obtainable at several elevated sites in Southern California and Arizona. In the use of a large solar image, which is so essential to further progress in spectroheliographic work, good day conditions are absolutely required. Professor HUSSEY's investigations show that Mt. Wilson, near Pasadena, is possessed of unusually favorable conditions of seeing, both by day and by night. Professor HUSSEY's further report on his search for suitable sites in Australia will be awaited with great interest.

It is gratifying to be able to add, from press reports, that Dr. HALE has been given a preliminary grant of \$10,000 by the Carnegie Institution, and that he, with two assistants, is now installing the Snow horizontal telescope of the Yerkes Observatory and other apparatus at the summit of Mt. Wilson.

The two projected substations are to be devoted primarily to the determination of the solar constant at different altitudes, and its possible variation, together with researches on atmospheric absorption. The instruments needed would be the same at each station, a 16-inch cœlostat and spectrobolometer for the solar-constant work. One station will be located on as high a mountain as will be found practicable and the other at its base. Mt. Whitney has been suggested as a very favorable

site, but this point will be investigated further before any definite recommendation is made as to the location of the substations. It is purposed to continue the work at the main station throughout at least one sun-spot period, and for two or three summers at the two substations.

With the foresight and thoroughness with which the committee has made its plans and preliminary investigations as an earnest of the wise future administration of its trust, with the powerful equipment for which these recommendations call, and with plans founded on the notable advances of the past twenty years, astrophysicists may well hope for a decade of unparalleled progress in the field of solar physics.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter, July 5, 8 ^h 54 ^m P.M.	Last Quarter, Aug. 4, 6 ^h 3 ^m A.M.
New Moon, " 12, 9 27 P.M.	New Moon, " 11, 4 58 A.M.
First Quarter, " 19, 12 49 P.M.	First Quarter, " 17, 8 27 P.M.
Full Moon, " 27, 1 42 A.M.	Full Moon, " 25, 5 2 P.M.

The Earth is in aphelion July 4th, 5 P.M., Pacific time.

Mercury is a morning star on July 1st, too near the Sun to be seen, rising about three quarters of an hour before sunrise. It rapidly approaches the Sun, passes superior conjunction, and becomes an evening star on July 9th. By August 1st it has receded far enough from the Sun to set rather more than an hour after sunset, and this interval does not change very much until after the middle of the month. It reaches greatest east elongation on the evening of August 19th. Its apparent distance from the Sun will then be $27^{\circ} 24'$. This elongation is much greater than the average greatest elongation, since the planet passed its aphelion on August 17th, only two days before. After passing greatest elongation the planet approaches